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HIGH YIELD SECOND PEAK Cu-Co CPP GMR MULTILAYER SENSORS

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We have fabricated and tested GMR magnetic flux sensors that operate in the CPP mode. This work is part of the ongoing effort to develop an ultra-high density magnetic sensor introduced at INTERMAG 96 [1]. We have addressed three problems encountered during testing of the devices described in [1]: the MR response was anisotropic, the response was non-uniform, and the operational yield of devices was low. We have also changed from the Cu-Co third peak layer spacing to the second peak layer spacing to take advantage of the larger MR response.

The processes developed to fabricate these sensors have been previously described [1]. We have, however, made two significant modifications. First, contact to the sensor is made through a metal conduit deposited *in situ* with the multilayers. This is done in place of the electroplating processes described in [1]. This configuration ensures a good interface between the top of multilayer stack and the top electrode and a continuous, conductive current path to the sensor. The consequences of this modification are an increase in yield of operational devices to ≥90% per wafer, the reduction of the effective contact resistance by a factor of two and of the variation in uniformity to ≤3%, and the elimination MR response anisotropy. Second, the as-deposited multilayer sensor has been changed from [Cu 30 Å/Co 20 Å]$_{18}$ (third peak) to [Cu 20.5 Å/Co 12 Å]$_{30}$ (second peak). The second peak film resistivity is 18.4 μΩ-cm. The sheet film CIP MR response is 25% for second peak multilayers and 8% for third peak multilayers. The saturation field, however, for both multilayer configurations is approximately 400 Oe.

The shape and dimension of CPP sensors described here are defined by electron beam lithography. The exposures are done on an *in situ* deposited multi-metal stack. The stack includes the lower electrode ([Si 15 Å/Mo 30 Å]$_{105}$), the multilayer sensor, and the top metal conduit ([Cu 200 Å]$_{30}$). The as-exposed features are written in negative resist and are nominally 0.46 μm diameter circles. The etch is done using an ECR reactor. Because the ECR etch used is primarily a physical etch, Cu is re-deposited on the inactive sidewalls of the pedestals. The consequence is an expansion of the sensor diameter. The SEM shown in Fig. 1 shows the Cu/[Cu-Co] pedestal after the ECR etch. The post-etch diameter is approximately 1.5 μm. The top and bottom contacts are electrically isolated by a PECVD Si_3N_4 film. Chemical mechanical polishing exposes the top Cu conduit and a 600 nm Cu film is deposited and patterned to form the top electrode. The contacts are configured for four-point-probe quasi-static testing.

Figure 2 shows the CPP MR response from twenty devices on a single substrate. The columns are perpendicular to the major flat. The sensors are separated by 15 mm. The CPP MR values were determined by assuming a 1.5 μm diameter sensor. The CPP MR response averaged over twenty devices on a four inch silicon substrate is 28% ± 6%. The MR response decreases radially from the substrate center. The average center MR response is 34% ± 4% and the average MR response at the periphery is 24% ± 3%. Figure 3 shows the normalized CPP and CIP second peak MR response curves. The CIP MR response is shown for reference and is 25%. The CPP MR response is 39%. The saturation field and hysteresis are closely matched indicating that the processes used to fabricate these sensors do not significantly alter their MR response.

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Figure 1. SEM micrograph of the Cu-Co pedestal after the ECR etch. The base diameter is 1.5 μm and the height is 1.1 μm.

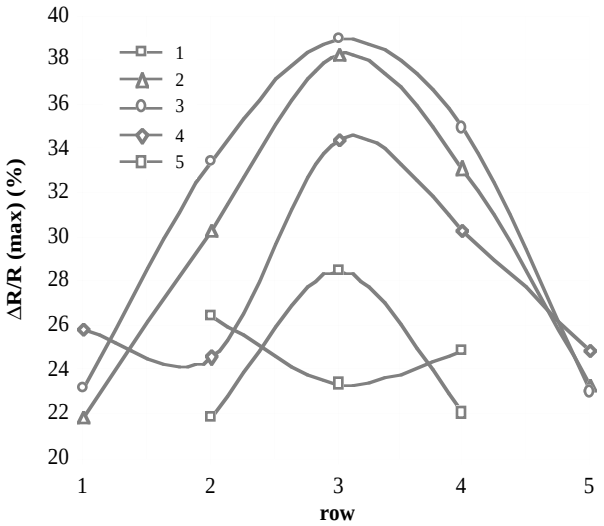

Figure 2. The second peak CPP MR response of twenty devices from a single substrate. The maximum response is 39%. The average response from the nine devices at the substrate center is 34% and from the twelve at the periphery is 24%.

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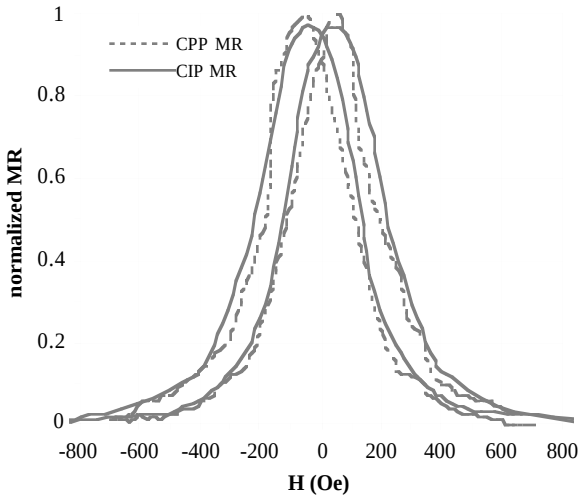

Figure 3. The normalized second peak CPP MR response and CIP MR response. The CPP MR response is 39% and the CIP MR response is 25%.

[1] J. Spallas, Y. Huai, S. Vernon, B. Fuchs, A. Hawryluk, B. Law, D. Kroes, M. Thomas, D. O'Kane, Z Tan, and D. Kania, "Perpendicular current giant magnetoresistance in a 0.4 μm diameter GMR Co-Cu multilayer sensor," IEEE Trans. Magn., 32 **(5)** pp. 4710-4712 (1996).